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[Title of the Invention] LIQUID CRYSTAL DISPLAY DEVICE AND LIQUID CRYSTAL DISPLAY DEVICE MANUFACTURING METHOD

[Abstract]

[Object] There is provided a liquid crystal display device having an improved temperature characteristic in a display quality, and a low degradation of the display quality caused by the temperature change, using a hard pillar shaped spacer in small elasticity.

[Solving Means] A liquid crystal display device comprising: a pair of substrates 1 and 2 having transparent electrodes 5 and 6 thereon, a spacer 3 arranged between the pair of the substrate 1 and 2 for maintaining a substrate gap to be constant; and a liquid crystal layer 4 encapsulated between the substrates 1 and 2, in which the spacer 3 is elastic, and for a temperature change within the temperature range available in the liquid crystal display device, a sum of a repulsive force of the spacer 3 and an inner pressure of the liquid crystal layer 4 is always almost 1 pressure, and in addition, inner pressures of the spacer 3 and the liquid crystal layer are linearly changed, respectively.

[Claims]

[Claim 1] A liquid crystal display device having a

pillar shaped spacer arranged between a pair of substrates for maintaining a substrate electrode to be constant, and a liquid crystal layer encapsulated between the substrates,

wherein the spacer is elastic; and

wherein, for a temperature change within a temperature range available in the liquid crystal display device, a sum of a repulsive force of the spacer and an inner pressure of the liquid crystal layer is always approximately the same as the atmospheric pressure.

[Claim 2] The liquid crystal display device according to Claim 1,

wherein a sum of the repulsive force of the spacer and the inner pressure of the liquid crystal layer is always approximately the same as the atmospheric pressure, and

wherein the inner pressures of the spacer and the liquid crystal layer are linearly changed, respectively.

[Claim 3] A liquid crystal display device having a pillar shaped spacer arranged between a pair of substrates for maintaining a substrate electrode to be constant, and a liquid crystal layer encapsulated between the substrates,

wherein the spacer is elastic; and

wherein, for a temperature change within a temperature range from the room temperature to the highest operating temperature of the liquid crystal display device, a sum of a repulsive force of the spacer and an inner pressure of the

liquid crystal layer is always approximately the same as the atmospheric pressure.

[Claim 4] The liquid crystal display device according to Claim 3,

wherein a sum of the repulsive force of the spacer and the inner pressure of the liquid crystal layer is always approximately the same as the atmospheric pressure, and

wherein the inner pressures of the spacer and the liquid crystal layer are linearly changed, respectively.

[Claim 5] A liquid crystal display device having a pillar shaped spacer arranged between a pair of substrates for maintaining a substrate electrode to be constant, and a polymer dispersed type liquid crystal layer including a liquid crystal encapsulated between the substrates and a polymer compound,

wherein the spacer is elastic; and

wherein, for a temperature change within a storage temperature range of the liquid crystal display device, a sum of a repulsive force of the spacer and an inner pressure of the liquid crystal layer is always approximately the same as the atmospheric pressure.

[Claim 6] The liquid crystal display device according to Claim 5,

wherein a sum of the repulsive force of the spacer and the inner pressure of the liquid crystal layer is always

approximately the same as the atmospheric pressure, and

wherein the inner pressures of the spacer and the liquid crystal layer are linearly changed, respectively.

[Claim 7] The liquid crystal display device according to any one of Claims 1, 3, and 5,

wherein the spacer is directly formed on at least one side of the pair of substrates through a pattering process.

[Claim 8] The liquid crystal display device according to Claim 7,

wherein the spacer is selected from a group consisting of a polystyrene based polymer compound, an acrylic based polymer compound, a polyester based polymer compound, a silicon based polymer compound, a polycarbonate based polymer compound, a polysiloxane based polymer compound, a polyethylene based polymer compound, a polyurethane based polymer compound, and a combination thereof including any one or more materials

[Claim 9] The liquid crystal display device according to any one of Claims 1, 3, 5, and 7,

wherein the spacer is formed in a tapered shape from one substrate toward the other substrate.

[Claim 10] The liquid crystal display device according to any one of Claims 1, 3, 5, and 7,

wherein the spacer is formed in a perfect hollow construction or a partial hollow construction between the

pair of substrates.

[Claim 11] The liquid crystal display device according to any one of Claims 1, 3, 5, and 7,

wherein the spacer has a longitudinal distribution in a direction perpendicular between the pair of substrates.

[Claim 12] The liquid crystal display device according to Claim 11,

wherein, for the length in the direction perpendicular between the pair of substrates, the spacer has a distribution having a mean and a derivative; and

wherein the derivative is approximately in a range of 3% to 6% of the mean value.

[Claim 13] The liquid crystal display device according to any one of Claims 1, 3, 5, and 7,

wherein formation density of the spacers is in a range of $5/mm^2$ to $200/mm^2$.

[Claim 14] The liquid crystal display device according to any one of Claims 1, 3, 5, and 7,

wherein the spacer is formed on a light shielding portion of at least one of the pair of substrates.

[Claim 15] The liquid crystal display device according to any one of Claims 1, 3, 5, and 7,

wherein the inner pressure of the liquid crystal layer is in a range of 0 kg/cm^2 to 0.9 kg/cm^2.

[Claim 16] A liquid crystal display device

manufacturing method, the liquid crystal display device having a pillar shaped spacer arranged between a pair of substrates for maintaining a substrate electrode to be constant, and a liquid crystal layer encapsulated between the substrates, the method comprising:

forming a plurality of spacers on at least one of the pair of substrates, and performing a process to give a predetermined amount of elasticity to the spacer;

forming the liquid crystal layer encapsulated between the pair of substrates having the spacer formed thereon; and

while or after forming the liquid crystal layer, uniformly pressing between the substrates in a pressure of approximately 0.1 kgf/cm^2 to 1.0 kgf/cm^2.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a liquid crystal display device and liquid crystal display device manufacturing method for use in, for example, an optical shutter and the like.

[0002]

[Description of the Related Art]

In a conventional liquid crystal display device in combination with a typical twisted nematic liquid crystal

(hereinafter, referred to as a TN liquid crystal) and an active matrix, a TN liquid crystal is interposed between two electrode-attached substrates, a voltage is applied between the substrates, and an alignment state of the liquid crystal molecules varies according to the applied voltage. The liquid crystal molecule has an optical transmission ratio changed according to the alignment state. Like this, the TN liquid crystal uses a scheme in which an optical transmission ratio is controlled by the voltage. The liquid crystal display device includes an active matrix substrate having switching elements and a pixel electrodes formed thereon, the switching element controlling whether or not a voltage is applied, represented as a thin film transistor (hereinafter, referring to as a TFT); a counter substrate; a liquid crystal encapsulated between two substrates; and a polarization plate arranged outside the two substrates. Using the voltage applied between the electrodes formed on the two substrates, the liquid crystal molecule changes an alignment state and changes an optical transmission ratio.

[0003].

However, in the typical liquid crystal display device, when a viewing angle, i.e., an angle to view a screen, is changed, optical rotation of transmission light is changed for an observer, so that a shading state is changed. For example, when seen from a front surface of the perpendicular

direction to the screen displaying white color, i.e., from the normal direction of the screen, an image having a good contrast is shown, while viewing the same screen from a slanted downward direction rather than the normal direction to the screen causes the image to be seen blurred. In addition, when seen from the downward direction, there occurs a so-called gray level inversion phenomenon that inverts shading. In addition, when seen from a slanted upward direction, the image is seen as white. The phenomenon occurs since displaying is performed in a manner such that an electric field is applied to the liquid crystal in a normal direction to the substrate, to lift the liquid crystal molecule based on an electric field direction, to thus control the optical rotation, and that a lifting direction of the liquid crystal molecule is determined. In order to obtain uniformity of a cell thickness, a plurality of fine beads, called as spacers, are scattered, which causes a so-called rough feeling and gives a bad effect on the display quality.

[0004]

In addition, as a method of improving the viewing angle problem, recently, an in-plane switch has drawn an attention. While the conventional liquid crystal display device applies the electric field in the normal direction to the substrate, and control an alignment state of the liquid crystal, as

described above, the in-plane switching controls the liquid crystal in a horizontal direction parallel to the substrate. This method provides a wide viewing angle in principle, and since there is a small change in color, it is considered as the most effective proposal. Like this, the viewing angle of the in-plane liquid crystal display device is significantly larger than the conventional TN type, but there are many light shielding portions such as a common electrode, a source electrode, and a switch electrode, so that an aperture ratio of the pixel is lower than the conventional TN type. For this reason, the bad effect on the display quality given from a plurality of spacer particles scattered to obtain a cell thickness is larger than the convention TN type.

[0005]

To solve these problems and obtain a favorable display quality, several methods are employed such as forming a pillar shaped spacer on a light shield portion on the active matrix substrate on which the switching devices such as TFTs are formed, or forming a pillar shaped spacer on the light shielding portion represented as a black matrix in a pixel portion of a color filter.

[0006]

For the conventional TN type, a construction that renders scattering of the spacer particles unnecessary has

been proposed. For example, Japanese Unexamined Patent Application Publication No. 7-281295 discloses a liquid crystal display device, in which protrusion portions are arranged at both substrates, i.e., the active matrix substrate and a substrate having a color filter formed thereon, and brought in touch with each other to serve as the spacer pillar.

[0007]

For the in-plane switching, Japanese Unexamined Patent Application Publication No. 6-214224 discloses a liquid crystal display device not using a spacer particle. In the liquid crystal display device, both the common electrode and the pixel electrode (source electrode) are formed to stand normal to substrate, and these two electrodes are used as a spacer (pillar), so that the spacer particles are not required.

[0008]

In addition, for a liquid crystal display device having an active matrix type substrate including switching elements such as TFTs in combination with a conventional polymer dispersed type liquid crystal (hereinafter, referred to as PDLC), a liquid crystal layer, in which liquid crystal molecules are dispersed in a droplet shape or a net shape into a polymer compound having a matrix type construction (hereinafter, referred to as a polymer matrix), is inserted

into two substrates having electrodes. While the voltage is applied, two molecule constructions are designed such that a refractive index of a liquid crystal molecule aligned in an applied direction and a refractive index of the polymer matrix are the same. When the voltage is applied, the refractive indices of the liquid crystal molecule and the polymer matrix are the same, so that light incident on the PDLC layer is transmissive light. With respect to this, when the voltage is not applied, an alignment direction of the liquid crystal molecule faces in a disordered direction. For this reason, refractive indices between the polymer matrix and the liquid crystal molecule are typically different. Therefore, light incident on the PDLC layer becomes scattering light. Like this, light incident on the PDLC is switched between a transmitting state and a scattering state according to whether or not the voltage is applied.

[0009]

For the conventional polymer dispersed type liquid crystal display device, a number of fine beads called as spacers are scattered to obtain a cell thickness that performs a favorable display quality. In these polymer dispersed type liquid crystal display devices, a projection display for transmitting light from a lamp having high brightness and enlarging and transmitting the image on a

screen or a reflection type display for performing display using external light with a reflection plate attached in the liquid crystal display device are used.

[0010]

[Problems to be Solved by the Invention]

Spacers formed in advance on the substrate for use in the conventional TN type liquid crystal display device, or the in-plane switching liquid crystal display device are arranged on a light shielding portion, so that the spacers in the liquid crystal display device may have a low distribution density in appearance. However, on the contrary, there is a problem in that a display quality is degraded due to a temperature change. This will now be described with reference to Fig. 12.

[0011]

First, due to a change from the room temperature to the low temperature, there is a low temperature discharge problem. When the liquid crystal display device 100 is left under the low temperature, a volume of the liquid crystal molecule is reduced. At this time, it is necessary that a cell be contracted, i.e., becomes thinner, in the direction of the cell thickness, following a volume contraction of the liquid crystal molecule. The low temperature discharging 108 refers to a phenomenon that vacuum bubbles are produced in the liquid crystal layer since the cell thickness cannot

follow the volume extraction of the liquid crystal molecule. When the spacer 105 formed by patterning on the substrate is solid, the spacer 105 blocks the contraction of the cell thickness in following the volume contraction of the liquid crystal 104 under the low temperature, so that the low temperature discharging 108 is easily provided. With respect to ensuring a favorable display quality without tracing the cell thickness under the low temperature and a rough feeling, the spacer having an appropriate elasticity is preferably used.

[0012]

In addition, while changing from the room temperature to a high temperature, there is a display spot problem. This is due to an increasing non-uniform cell thickness caused by a temperature increase. The liquid crystal molecule encapsulated into the liquid crystal display device is expanded through heating. As a result of expansion due to a temperature increase of the liquid crystal molecule, a volume in the liquid crystal display device is increased. The increase in the volume causes a change of the gap between the substrates, i.e., a change of the cell thickness. At this time, in the conventional liquid crystal display device, a pillar shaped spacer cannot follow an increase of the cell thickness. For this reason, a change of the cell thickness is dominated by heat expansion of the liquid

crystal molecule, so that there is a problem in that the non-uniformity of the cell thickness increases and thus the uniformity of the display quality is damaged.

[0013]

In addition, with respect to a polymer dispersed type liquid crystal display device, in particular, a projection display which is a scheme that transmits light a liquid crystal display device from the light source, expands and transmits the image on a screen, the spacer is expanded to guarantee the cell thickness. For the PDLC projection display, when the voltage is not applied, it becomes a light scattering mode, i.e., a black display mode, so called a normally black mode. At this time, when the conventional non-colored spherical spacer is used, a portion where the spacers are scattered does not cause the scattering, and thus light is leaked out. For this reason, the black brightness at the time of displaying black color is proportional to dispersion density of the spherical spacer, and consequently, causes contrast degradation as a screen.

[0014]

In order to suppress contrast degradation using block brightness improvement due to an optical leakage from the spacer when the voltage is not applied, spacers added with coloring agent having light shielding and block color may be used. The optical leakage is prevented using the colored

spacer, so that the degradation of the contrast can be prevented, but a new problem arises. In order to guarantee the higher contrast, display uniformity in the high gray level becomes critical. For this reason, the uniformity of the cell thickness needs to be improved. In order to improve the uniformity of the cell thickness, the dispersion density of the spacers should be increased. When the dispersion density of the spacer increases, the spacers contact with each other at the time of scattering the spacer, and a lump is easily formed so that a rough feeling can be easily provided. In addition, the spacer itself expands, so that the rough feeling is easily provided when the voltage is applied. Like this, to order to guarantee a favorable display quality including contrast and gray level, there is a problem such as spacer shape and characteristics.

[0015]

In addition, for the conventional combination of the spacers directly formed on the substrate and the polymer dispersed type liquid crystal display device, there was a problem of reliability at the storage temperature, i.e., reliability when left in the high temperature. For the polymer dispersed type liquid crystal display device, the following problems can occur due to a rapid change of the temperature. This will now be described with reference to Fig. 13.

[0016]

Fig. 13a shows a state of a liquid crystal display device 200 in case of the room temperature (e.g., 20℃). In Fig. 13a, the spacer 206 has the same size as the gap width, so that little pressure is received from the glass substrates 201 and 202.

[0017]

Fig. 13b shows a state of a liquid crystal display device in case of the high temperature (e.g., 85℃). In this case, a polymer matrix 205 and a liquid crystal 204 expand through heating, and the inner pressure of the liquid crystal layer 209 increases. The central portion of the glass substrates 201 and 202 is not fixed through the sealing member 203 unlike the peripheral portion, so that the central portion is deformed as shown in Fig. 13b due to an increased inner pressure, and a gap width grows larger as closing to the central portion from the peripheral portion. As a result, the expanded liquid crystal 204 focuses on the central portion.

[0018]

When temperature rapidly turns and increases from the state of Fig. 13b, the liquid crystal layer 209 contracts. At this time, the liquid crystals focused on the central portion cannot go back full into the original state, and the most of them are left on the central portion. Therefore, as

shown in Fig. 13c, a gap width between the glass substrates 201 and 202 becomes the other state at each portion. Like this, due to expansion and contraction of the liquid crystal layer caused by a rapid change of the temperature for the conventional polymer dispersed type liquid crystal display device, the thickness of the liquid crystal layer becomes abnormal, and as a result, there is a problem in that the display quality is significantly degraded.

[0019]

[Problems of the Prior Art]

The above problems of the prior art will be summarized as follows.

[0020]

(1) For the liquid crystal display device such as the TN mode, display quality is degraded when used at the low temperature, due to the low temperature discharging caused by a rapid temperature change from the room temperature to the low temperature.

[0021]

(2) For the liquid crystal display device such as the TN mode or the polymer dispersed type liquid crystal display device, display quality is degraded when used at the high temperature, due to the non-uniform cell thickness caused by a rapid temperature change from the room temperature to the high temperature.

[0022]

(3) When the polymer dispersed type liquid crystal display device is left in a state where a temperature is rapidly changed, the thickness of the liquid crystal layer becomes non-uniform due to expansion and contraction of the liquid crystal layer, and accordingly, the display quality is degraded.

[0023]

(4) With an increasing formation density of the spacer and arrangement of the spacer, the rough feeling of the image is generated so that display quality is degraded.

[0024]

The present invention is contrived to solve the problems of the prior art, and an object of the present invention is to provide a liquid crystal display device in which temperature characteristic of the display quality is improved since the pillar shaped spacer is stiff and the elasticity is low, and the display quality is less degraded due to the temperature change.

[0025]

More specifically, another object of the present invention is to provide a liquid crystal display device having a favorable display quality without a low temperature discharging when used, so called, in the low temperature, in which, when the liquid crystal molecule contracts due to a

rapid temperature change from the room temperature to the low temperature, the liquid crystal display device can follow spacer.

[0026]

In addition, still another object of the present invention is to provide a liquid crystal display device having a favorable display quality without a non-uniform cell thickness even when used at the high temperature.

[0027]

In addition, still another object of the present invention is to provide a polymer dispersed type liquid crystal display device having a high display quality without generating non-uniform cell thickness at the high temperature and a low temperature discharging in the operating temperature range.

[0028]

In addition, still another object of the present invention is to provide a polymer dispersed type liquid crystal display device having a favorable display quality without generating non-uniform thickness of the liquid crystal layer due to expansion and contraction of the liquid crystal layer, even when the polymer dispersed type liquid crystal display device is left in a temperature changing state.

[0029]

In addition, still another object of the present invention is to provide a liquid crystal display device having a favorable display quality without a rough feeling that can correspond to a high contrast and high gray level, by forming a pillar shaped spacer (meaning non-spherical spacer) in advance on a light shielding portion of the counter substrate or the active matrix substrate.

[0030]

In addition, an object of the present invention is to provide a method of manufacturing the liquid crystal display device.

[0031]

[Means for Solving the Problems]

In order to accomplish the above-mentioned objects, the present invention includes the following means.

[0032]

An aspect of the present invention claimed in Claim 1 of the present invention provides a liquid crystal display device having a pillar shaped spacer arranged between a pair of substrates for maintaining a substrate electrode to be constant, and a liquid crystal layer encapsulated between the substrates. Here, the spacer may be elastic, and, for a temperature change within a temperature range available in the liquid crystal display device, a sum of a repulsive force of the spacer and an inner pressure of the liquid

crystal layer may be always approximately the same as the atmospheric pressure.

[0033]

With the above arrangement, the spacer is always elastically deformed within the operating temperature range of the liquid crystal display device. As a result, the low temperature discharging phenomenon can be prevented, and in addition, non-uniform cell thickness at the high temperature can be prevented, and thus display quality can be improved.

[0034]

In addition, by giving proper elasticity to the spacer, the distribution density of the spacer can be established in a range that does not give a rough feeling. From this point of view as well, the display quality can be improved.

[0035]

In addition, the liquid crystal layer may be a TN type liquid crystal layer, an STN type liquid crystal layer, as well as a polymer dispersed type liquid crystal layer.

[0036]

The invention claimed in Claim 2 is characterized in that, for the liquid crystal display device claimed in Claim 1, a sum of the repulsive force of the spacer and the inner pressure of the liquid crystal layer may be always approximately the same as the atmospheric pressure, and the inner pressures of the spacer and the liquid crystal layer

may be linearly changed, respectively.

[0037]

With the above arrangement, when the inner pressures of the spacer and the liquid crystal layer are linearly changed, the uniformity of the cell thickness can be further improved.

[0038]

Another aspect of the present invention claimed in Claim 3 provides a liquid crystal display device having a pillar shaped spacer arranged between a pair of substrates for maintaining a substrate electrode to be constant, and a liquid crystal layer encapsulated between the substrates. Here, the spacer may be elastic, and, for a temperature change within a temperature range from the room temperature to the highest operating temperature of the liquid crystal display device, a sum of a repulsive force of the spacer and an inner pressure of the liquid crystal layer may be always approximately the same as the atmospheric pressure.

[0039]

With the above arrangement, the non-uniform cell thickness can be prevented at the high temperature, and display quality can be improved.

[0040]

The invention claimed in Claim 4 is characterized in that, for the liquid crystal display device claimed in Claim 3, a sum of the repulsive force of the spacer and the inner

pressure of the liquid crystal layer may be always approximately the same as the atmospheric pressure, and the inner pressures of the spacer and the liquid crystal layer may be linearly changed, respectively.

[0041]

With the above arrangement, the uniformity of cell thickness at the high temperature can be further improved.

[0042]

Still another aspect of the present invention claimed in Claim 5 provides a liquid crystal display device having a pillar shaped spacer arranged between a pair of substrates for maintaining a substrate electrode to be constant, and a polymer dispersed type liquid crystal layer including a liquid crystal encapsulated between the substrates and a polymer compound. Here, the spacer may be elastic, and, for a temperature change within a storage temperature range of the liquid crystal display device, a sum of a repulsive force of the spacer and an inner pressure of the liquid crystal layer may be always approximately the same as the atmospheric pressure.

[0043]

When the polymer dispersed type liquid crystal display device is provided, the spacer is always elastically deformed within the storage temperature range. As a result, a distortion of the gap width (i.e., derivative of the

thickness of the liquid crystal layer) between substrates due to a rapid change of the temperature can be prevented, so that cell thickness can maintain constant, and the display quality can be improved.

[0044]

The invention claimed in Claim 6 is characterized in that, for the liquid crystal display device claimed in Claim 5, a sum of the repulsive force of the spacer and the inner pressure of the liquid crystal layer may be always approximately the same as the atmospheric pressure, and the inner pressures of the spacer and the liquid crystal layer may be linearly changed, respectively.

[0045]

With the above arrangement, when the inner pressures of the spacer and the liquid crystal layer are linearly changed, uniformity of the cell thickness can be further improved.

[0046]

The invention claimed in Claim 7 is characterized in that, for the liquid crystal display device claimed in any one of Claims 1, 3, and 5, the spacer may be directly formed on at least one side of the pair of substrates through a pattering process.

[0047]

With the above arrangement, considering the size and distribution density of the spacer, a spacer having desired

elasticity can be obtained.

[0048]

The invention claimed in Claim 8 is characterized in that the spacer may be selected from a group consisting of a polystyrene based polymer compound, an acrylic based polymer compound, a polyester based polymer compound, a silicon based polymer compound, a polycarbonate based polymer compound, a polysiloxane based polymer compound, a polyethylene based polymer compound, a polyurethane based polymer compound, and a combination thereof including any one or more materials

[0049]

The invention claimed in Claim 9 is characterized in that, for the liquid crystal display device claimed in any one of Claims 1, 3, 5, and 7, the spacer may be formed in a tapered shape from one substrate toward the other substrate.

[0050]

With the above arrangement, an elastic spacer having desired elasticity can be obtained.

[0051]

The invention claimed in Claim 10 is characterized in that, for the liquid crystal display device claimed in any one of Claims 1, 3, 5, and 7, the spacer may be formed in a perfect hollow construction or a partial hollow construction between the pair of substrates.

[0052]

With the above arrangement, an elastic spacer having desired elasticity can be obtained.

[0053]

The invention claimed in Claim 11 is characterized in that, for the liquid crystal display device claimed in any one of Claims 1, 3, 5, and 7, the spacer may have a longitudinal distribution in a direction perpendicular between the pair of substrates.

[0054]

In addition, the invention claimed in Claim 12 is characterized in that, for the length in the direction perpendicular between the pair of substrates, the spacer may have a distribution having a mean and a derivative, and the derivative may be approximately in a range of 3% to 6% of the mean value.

[0055]

With the above arrangement, considering a distribution of the height of the spacer, optimal elasticity can be given to the spacer.

[0056]

The invention claimed in Claim 13 is characterized in that, for the liquid crystal display device claimed in any one of Claims 1, 3, 5, and 7, formation density of the spacers may be in a range of $5/mm^2$ to $200/mm^2$.

[0057]

With the above arrangement, considering a distribution of the formation density of the spacer, optimal elasticity can be given to the spacer.

[0058]

The invention claimed in Claim 14 is characterized in that, for the liquid crystal display device claimed in any one of Claims 1, 3, 5, and 7, the spacer may be formed on a light shielding portion of at least one of the pair of substrates.

[0059]

With the above arrangement, an aperture ratio can be improved.

[0060]

The invention claimed in Claim 15 is characterized in that, for the liquid crystal display device claimed in any one of Claims 1, 3, 5, and 7, the inner pressure of the liquid crystal layer may be in a range of 0 kg/cm^2 to 0.9 kg/cm^2.

[0061]

When the spacer is in the elastically deformed state, the inner pressure of the liquid crystal layer is also smaller than the atmospheric pressure. Therefore, the elastically deformed state of the spacer can also be defined from the inner pressure of the liquid crystal layer.

[0062]

Still another aspect of the present invention claimed in Claim 16 provides a liquid crystal display device manufacturing method, the liquid crystal display device having a pillar shaped spacer arranged between a pair of substrates for maintaining a substrate electrode to be constant, and a liquid crystal layer encapsulated between the substrates, the method comprising: forming a plurality of spacers on at least one of the pair of substrates, and performing a process to give a predetermined amount of elasticity to the spacer; forming the liquid crystal layer encapsulated between the pair of substrates having the spacer formed thereon; and while or after forming the liquid crystal layer, uniformly pressing between the substrates in a pressure of approximately 0.1 kgf/cm^2 to 1.0 kgf/cm^2.

[0063]

The reason the pressing pressure to the substrate is restricted is that, when it is less than 0.1 kgf/cm^2, the spacer cannot be elastically deformed, and when it is more than 1.0 kgf/cm^2, the spacer is plastically deformed.

[0064]

[Embodiments]

Preferred embodiment of the present invention will now be described with reference to the accompanying drawings.

[0065]

(First Embodiment)

Fig. 1 is a simplified cross sectional view of a liquid crystal display device according to a first embodiment of the present invention. The liquid crystal display device includes a pair of glass substrates 1 and 2; a pillar shaped spacer 3 arranged between the substrates 1 and 2 for maintaining a substrate gap to be constant; and a liquid crystal layer 4 encapsulated between the substrates 1 and 2. Transparent electrodes 5 and 6 are formed on the inner side of the glass substrate 1 and 2. In addition, in Fig. 7, reference numeral 7 refers to a sealing portion fixed to the substrates 1 and 2 for encapsulating the liquid crystal layer 4.

[0066]

The spacer 3 is elastic, and becomes an elastically deformed state within an operating temperature range (0℃ to 85℃). In other words, in conjunction with a temperature change within the operating temperature range of the display device, a sum of the repulsive force of the spacer 3 and the inner pressure of the liquid crystal layer 4 is always approximately 1 atmospheric pressure, and in addition, the inner pressures of the spacer 3 and the liquid crystal layer 4 are linearly changed, respectively. With the above arrangement, at the low temperature, the display without the low temperature discharging can be enabled, and at the high

temperature as well, the non-uniform cell thickness can be prevented, so that the display quality is improved. In addition, in order to increase the uniformity of the cell thickness, it is necessary for the distribution density of the spacer to be large, however, according to the present invention, the spacer 3 has proper elasticity, so that the distribution density of the spacer can be established such that the rough feeling is not generated not to mention the conventional level of the distribution density of the spacer. Therefore, sufficient uniformity of the cell thickness is obtained, and in addition, the rough feeling due to an increasing distribution density of the spacer can be prevented, so that display quality can be improved.

[0067]

A method of manufacturing the liquid crystal display device with the above arrangement will now be described.

[0068]

First, based on the same method as in the prior art, a pair of substrates 1 and 2 having transparent electrodes 5 and 6 formed thereon is provided. Next, the spacer 3 is formed on the substrate 1.

[0069]

A method of forming the spacer 3 will be specifically described with reference to Fig. 2. Here, as an example, it will be described in the context that a photosensitive

polymer including carbon is used in the substrate 1 on which the transparent electrode 5 is formed. An acrylic based negative type resist was prepared such that a solid content ratio is 38%, and a carbon power was 5% mixed. Here, the carbon fiber is means for coloring the pillar shaped spacer in black color, and may be a material that absorbs visible light. A uniform resist layer 10 was formed on the glass substrate 1 using a spinner (Fig. 2b). This was performed with the number of rotation of 5000 rpm for 5 seconds, and of 1300 rpm for 30 seconds. Next, the resist layer 10 is pre-baked for 3 minutes at 80°C. In addition, as shown in Fig. 2c, a predetermined type of pillar shaped spacer 3 described below was formed through a photolithography technology using a mask 11. In addition, intensity of UV illumination herein was 15 mW/cm^2 and an exposed time was 3 second.

[0070]

The conventional pillar shaped spacer has low elasticity, and non-uniform spacer is difficult to control, so that according to the present invention, the elasticity is given to the spacer in the following method.

[0071]

First, as a first method, the spacer having a shape as shown in Fig. 3 was formed by such as reviewing a developing condition. In addition, Fig. 3a shows a spacer in the

elastically deformed state, and Fig. 3b shows a spacer in the state before elastically deformed. Specifically, the method involves that the spacer having an arrangement where an end surface becomes thinner such as a cone 3A, or a triangular pyramid 3C or a rectangular pyramid 3C or a polygonal pyramid 3D was formed, so that when pressed, the spacer 3 in the liquid crystal display device is elastically deformed.

[0072]

A second method involves that some or all of the inner portions 9 of the spacer 3 is in a hollow shaped state, as shown in Fig. 4, so that when pressed, the spacer 3 in the liquid crystal display device is elastically deformed.

[0073]

A third method involves mixing a rubber based resin power or a silicon based resin power in the resist to elasticized the spacer 3. A mixed amount of the resin power is effective in less than 3%, which can be elastically deformed. In addition, in case of the resin, it will not be limited hereto.

[0074]

A fourth method involves that a polymerization of the resist is lowered. By lowering the concentration of a bridge agent in the resist, elasticity was realized.

[0075]

A fifth method involves shortening both ends of the spacer pillar.

[0076]

With any one of the above methods, the elasticity can be given to the spacer.

[0077]

In the following example, the first method, i.e., a case where the rectangular pyramid 3c pillar shaped spacer 3 is used will be described. Specifically, the square pyramid shaped spacer 3 was formed with one side of the lower surface of 5 μm, by repeating an etching process through a photography technology. In addition, a detailed shape (e.g., area of the bottom surface, natural length, etc.) of a rectangular shaped spacer is established, considering the formation density of the spacer, and in addition, for any temperature of the maximum and minimum temperature of the operating temperature range, such that the elasticity is given as much as an amount of deformation in which the elastic deformation state can be maintained. For example, as shown in fig. 5a, an initial height of the pillar shaped spacer formed in the substrate is H1, and a height of the pillar shaped spacer in a state shown in fig. 5 having a predetermined cell thickness and pressed between the substrates is H2 (room temperature state). At this time, at the minimum temperature of the operating temperature

range, when a length in the direction of the cell thickness due to the heat contraction of the liquid crystal layer is m1, the height of the pillar shaped spacer is deformed to be m1, and in addition, at the height m1, the spacer is required to be an elastically deformed state. Further, in the same manner, for the maximum temperature of the operating temperature range, when the length in the direction of the cell thickness due to the heat expansion of the liquid crystal layer is m2, the height of the pillar shaped spacer is deformed to be m2 (here, m2 < m1), and in addition, at the height m2, the pillar shaped spacer is required to be the elastically deformed state. However, when the formation density of the spacer is extremely small, uniformity of the cell thickness is degraded, and otherwise, when it is too large, an optical leakage due to the spacer is large. Therefore, considering problems directed to the formation density of the spacer, and for any temperature of the maximum temperature and minimum temperature within the operating temperature range, it is necessary to establish the spacer shape such that the elastically deformed state can be maintained.

[0078]

Based on the foregoing consideration, according to the first embodiment of the present invention, a bottom surface of 5.00 μm, an average height of the spacer of 4.70 μm, a

derivative of about 3 %, and a formation density of about $300/mm^2$ are established. Next, post-baking is performed at 200℃. Next, a sealing portion 7 is printed on a peripheral portion of one substrate (Fig. 3e). Next, using a pressing device, the substrates 1 and 2 having a pair of transparent electrodes 5 and 6 in an overlapping state are pressed and heated, and the sealing portion 7 is cured (Fig. 3f). Next, the liquid crystal material is injected into a gap formed in the pair of the substrates 1 and 2 from an injecting port arranged a part of the sealing portion 7, to thus form the liquid crystal layer 4.

[0079]

Next, in order to set the cell thickness to be a predetermined value, the liquid crystal display device is pressed. The pressing value F was set to 0.3 kgf/cm^2. At this time, the spacer 3 is partially in the elastically deformed state.

[0080]

The cell thickness of the liquid crystal display device through the above processing can have a mean of 4.65 μm, and a derivative of 0.12 μm, and visibility or contrast of the liquid crystal display device was significantly improved. At this time, since the mean of the height of the spacer formed on the substrate surface is 4.70 μm, it will be appreciated that, in this state, a part of the spacer is in

the elastically deformed state. In addition, the bottom surface, the height, and the formation density of the pillar shaped spacer are not limited hereto, but when a bottom surface of more than 3 μm and less than 20 μm, the mean of the height of the spacer of more than 3 μm and less than 20 μm, and the formation density of the spacer of more than $5/mm^2$ and less than $2000/mm^2$ are provided, the present inventors checks that the spacer can sufficiently follow the temperature change.

[0081]

In addition, even when the elasticity is provided using the pillar shaped spacer as a hollow, the description on the rectangular shaped spacer is adapted. For the hollow shaped spacer, when a radius of an outer circle of more than 3 μm and less than 20 μm, a radius of an inner circle of more than 2 μm and less than 15 μm, a cross sectional area of more than 4 $μm^2$ and less than 140 $μm^2$, the mean of the height of the spacer of more than 3 μm and less than 20 μm, the formation density of the spacer of $5/mm^2$ and less than $2000/mm^2$ are provided, the present inventors checks that the spacer can sufficiently follow the temperature change.

[0082]

In addition, the above detailed number is described in the context that a negative type resist made of an acrylic based polymer compound is used for the spacer material. As

described below, even when other materials are used for the spacer material, considering the same manner as in the above acrylic based polymer compound, if the shape and the formation density of the shape is set to be within the optical range, advantageously, the spacer can sufficiently follow a temperature change.

[0083]

Next, the liquid crystal display device manufactured through the above method is exposed to an environment from the room temperature to -20° C. Hereinafter, this will be described with reference to Fig. 6. Fig. 6a shows a liquid crystal display device at the time of the room temperature. In this state, some or all of the spacers are elastically deformed. Fig. 6b is a diagram showing a liquid crystal display device state under the lower temperature. The thickness direction of the liquid crystal layer 4 contracts, due to the volume contraction under the low temperature. According to the present embodiment, the spacer 3 is also elastic, and can follow the contraction of the liquid crystal layer 4, so that the low temperature discharging phenomenon does not occur even under the lower temperature.

[0084]

In addition, the liquid crystal display device manufactured through the above method is exposed to an environment from 20℃ to 40℃. Hereinafter, this will be

described with reference to Fig. 6. Referring to Figs. 7a, 7b, and 7c, the structural change generated in the liquid crystal display device according to the present invention will now be described.

[0085]

First, Fig. 7a shows a liquid crystal display device state in the case of the room temperature (20℃ in the present embodiment). In this state, a pressure of a difference between the atmospheric pressure and the pressure to the substrates 1 and 2 of the liquid crystal layer 4 (hereinafter, referred to as an inner pressure of the liquid crystal layer 4) is applied to two sheets of glass substrates 1 and 2 from the outside, and as a result, the spacer 3 is compressed.

[0086]

Fig. 7b shows a liquid crystal display device when the liquid crystal display device at the room temperature of Fig. 7a is temperature increased to the maximum of the operating temperature. In this state, the inner pressure of the liquid crystal layer 4 is increased due to heating.

[0087]

According to the present embodiment, a line expansion coefficient of the spacer 3 is $7.0\text{~}10.0\times10^{-5}$ (1/K), and a line expansion coefficient of the liquid crystal material of the liquid crystal layer 4 is 7.0×10^{-4}(1/K). The increase of

the inner pressure of the liquid crystal layer 4 due to heating depends on the expansion of the liquid crystal molecule.

[0088]

Fig. 8 shows an example showing a relation between an inner Pressure Pi of the liquid crystal layer 4 and a repulsive force Pr of the spacer 3, when a temperature of the liquid crystal display device under a constant atmospheric pressure increases or decreases within a predetermined temperature range. In addition, in Fig. 8, the atmospheric pressure is 1.0 kgf/cm^2. The horizontal axis represents a temperature T in a range of 20℃ to 60℃. The vertical axis represents a pressure P in a range of 0.3 kgf/cm^2 to 0.7 kgf/cm^2. The solid line represents a pressure applied to the liquid crystal layer 4, i.e., an inner pressure Pi of the liquid crystal layer 4, and a dotted line L2 represents the pressure applied to the spacer 3, i.e., the repulsive force Pr of the spacer 3 per unit area. Hereinafter, the repulsive force of the spacer 3 per unit area is referred to as the repulsive force Pr of the spacer.

[0089]

Within the above temperature range, it will be appreciated that both the inner pressure of the liquid crystal layer 4 and the repulsive force Pr of the spacer exist, and their summation is the same as the atmospheric

pressure. In other words, the liquid crystal display device resists the atmospheric pressure through the inner pressure of the liquid crystal layer 4 and the repulsive force Pr of the spacer 3.

[0090]

When the inner pressure of the liquid crystal layer 4 increases in proportional to the increase of the temperature, the repulsive force Pr of the spacer 3 decreases, while the spacer 3 always has the repulsive force Pr in the temperature range (20℃ to 60℃) according to the present example. In other words, the compressed spacer lifts up the glass substrates 1 and 2 from the inside through the repulsive force Pr at a place where the liquid crystal layer 4 reaches, and then holds the compressed state. As a result, as shown in Fig. 7b, a gap width is uniformly widened other than the peripheral portion fixed to the sealing portion 7.

[0091]

Fig. 7c shows a liquid crystal display device with a temperature decreasing from the high temperature state shown in Fig. 7b to the room temperature. As shown in Fig. 7b, when the liquid crystal display device in the high temperature is cooled, the inner pressure of the liquid crystal layer 4 is reduced and the repulsive force Pr of the spacer 3 increases. In other words, the expanded liquid crystal layer 4 contracts while the glass substrates 1 and 2

and the spacer 3 always contact with each other. For this reason, the liquid layer 4 will not have a different degree of contraction depending on the location, and thus uniformly contracts on the overall place. As a result, even when the temperature drops from the high temperature state, it perfectly goes back to the original state (Fig. 7a), as shown in Fig. 7c.

[0092]

As a comparative example of the first embodiment, Fig. 14 shows a spacer state for a temperature change of the liquid crystal display device in the context that the hardened spacer 150 having a small elastic deformation is used, which shows a relation of the comparative example of Fig. 15 between the inner pressure of the liquid crystal layer 151 and the repulsive force of the spacer 150. At the high temperature, the spacer 150 cannot follow the expansion of the liquid crystal layer, and a central portion of the substrate is largely bended, so that display performance is degraded.

[0093]

This is also shown in Fig. 15. In other words, the repulsive force of the spacer is significantly reduced in conjunction with the increase of the temperature, and when exceeding a certain temperature, the repulsive force will be 0. This indicates that most of the spacers are far off from

the substrate. At the higher temperature, due to a tensile effect bonding the substrates, the central portion is floated up. In addition, in conjunction with the temperature increase, the inner pressure of the liquid crystal layer continues to increase. Therefore, in the comparative example, the operating temperature range is narrow, and in order to widen the operating temperature range, it will be appreciated that it is necessary to give the elasticity to the spacer.

[0094]

Therefore, according to the present embodiment, as long as the spacer 3 is elastically compressed, the distortion of the gap width between two sheets of glass substrates due to the temperature change, i.e., the derivative of the thickness Tc of the liquid crystal layer can be prevented. In addition, the temperature range is 20℃ to 60℃ in the foregoing description, however, from the experiment result of the present inventors, it was verified that the spacer can be followed even in the temperature range of 0℃ to 85℃. Therefore, as long as both the inner pressure of the liquid crystal layer 4 and the repulsive force Pr of the spacer 3 exist, and in addition, their summation is the same as the atmospheric pressure, the effect of the present invention can be obtained. For example, the liquid crystal display device has different operating temperature according to its

use, and it is necessary that non-uniformity be not generated within this operating temperature range. For example, while used in a car navigation system where there are lot of work to do in the car is set to be relatively high temperature, however, even in this case, the elasticity, the formation density, pushing thickness and the like of the spacer are optimized such that it is applicable. Besides, notebook personal computer use, personal computer monitor use, projection display use, portable data application use, and mobile telephone use, a reflection type liquid crystal TV monitor and the like use are also applicable in the same manner in the respective operating temperature ranges.

[0095]

In addition, as a result, a derivative of the cell thickness is not generated. In addition, the display spot is also prevented.

[0096]

An operational mode of the liquid crystal display device of the present invention may be any type of operational mode as long as the molecular alignment can be controlled by the electric field, however, it is particular advantageous to an IPS (in-plane switching), a TN mode, a STN (super twisted nematic) mode, and a ferroelectric liquid crystal mode. As a display mode of the liquid crystal display panel, either a normally black mode (NB) in which

when the voltage is not applied black color is displayed so that light is not transmitted, and a normally white mode (NW) in which when the voltage is not applied white color id displayed so that light is transmitted may be used. In terms of the formation density of the spacer, while about $300/mm^2$ is used in the present embodiment, about $10/mm^2$ to $2000/mm^2$ may also be applicable in the same manner. Here, as the formation density is larger, it is necessary to reduce the stress at the time of elastic deformation. Basically, when the means of the height of the spacer and the derivative thereof are the same, the stress of the spacer is inversely proportional to the formation density. When the formation density is less than $5/mm^2$, the spacer is not almost deformed at the time of applying stress, in order to maintain a constant cell thickness, and thus following characteristic is lost, and the low temperature discharging phenomenon or the non-uniformity of the cell thickness at the high temperature is generated. Like this, in order to maintain a favorable display quality, a certain degree of formation density is required. In addition when the formation density exceeds $2000/mm^2$, at the current state, it is difficult to form the spacer, which is impossible to implement. To obtain the following, more than two spacers having different sizes in the normal direction of the substrate surface may be formed. In addition, more than two

spacers having different elasticity may be formed within the surface.

[0097]

According to the present embodiment, in order to elastically deform some or all of the spacers, the pressure of 0.3 kgf/cm^2 is uniformly pressed between the substrates, for a process of encapsulating the liquid crystal material between the substrates, however, for example, the formation density, the elasticity, and the like of the spacer can be optimized so that it can be implemented in the same manner even in the uniform pressure from 0.1 kgf/cm^2 to 1.0 kgf/cm^2.

[0098]

Furthermore, while the present embodiment describes the elastic operation of spacer as a pressing value of the panel surface, it may be described as the inner press operation of the liquid crystal layer 4 in the liquid crystal display device. At this time, when the inner pressure of the liquid crystal layer 4 is approximately 0.1 kgf/cm^2 to 1.0 kgf/cm^2, it can be implemented in the same manner. Outside the above range, The cell thickness cannot follow the operation of the liquid crystal layer, so that it cannot be implemented.

[0099]

While the present embodiment uses a negative type resist consisting of an acrylic based polymer compound as the spacer material, the spacer may be selected from a group

consisting of a polystyrene based polymer compound, an acrylic based polymer compound, a polyester based polymer compound, a silicon based polymer compound, a polycarbonate based polymer compound, a polysiloxane based polymer compound, a polyethylene based polymer compound, and a polyurethane based polymer compound. In addition, copolymer and polymer alloy compound may also be used, which uses a combination thereof among the above compounds.

[0100]

In addition, according to the present embodiment, while a photolithography is performed on the substrate surface using the above material, and the spacer is directly formed, for example, the spacer may be formed, in the same manner, on a plastic substrate made of the compound through pressing and the like.

[0101]

In addition while the present embodiment has been described in the context that the glass substrate is used, a-Si TFT substrate using an amorphous silicon thin film as a switching element, a driver built in type polysilicon TFT substrate, and a low temperature poly silicon TFT, a high temperature poly silicon TFT substrate through thermal annealing, and a polysilicon substrate having metal catalyst crystallized in other methods, and further, two terminal type active matrix substrate having a thin film diode TFD

formed thereon may also be used.

[0102]

In addition, the spacer may be formed on the light shielding portion of the pixel portion of the color filter. At this time, when these spacers have elasticity enough to follow contraction of the liquid crystal molecule, at the time of temperature change from the room temperature to the lower temperature, it can be used in the same manner.

[0103]

(Second Embodiment)

Fig. 9 is a cross sectional view of a liquid crystal display device according to a second embodiment of the present invention. The present embodiment is characterized in that the polymer dispersed type liquid crystal display device including a polymer dispersed type liquid crystal layer 22 made of the liquid crystal 20 and the polymer matrix 21 is used instead of the liquid crystal layer 4. The polymer matrix 21 is a polymer compound having a 3-D net shaped construction. The liquid crystal 20 is a liquid crystal dispersed in the droplet shape into the polymer matrix 21 and the liquid crystal having a net shaped construction in which the liquid crystals dispersed in the droplet shape are interconnected. In addition, a volume ratio of the liquid crystal 20 to the polymer matrix 21 is approximately 4:1.

[0104]

The polymer dispersed type liquid crystal display device does not show a low temperature discharging phenomenon, unlike the TN type liquid crystal display device, the STN type liquid crystal display device, and the ferroelectric type liquid crystal display device. However, since fluidity of the liquid crystal is low, there is a problem in that the non-uniformity at the high temperature side may be conspicuously generated. In order to solve the problems, the polymer dispersed type liquid crystal display device according to the second embodiment of the present invention uses the pillar shaped spacer 3, in the same manner as the first embodiment. As a result, when used in the projection display, a favorable display quality can be maintained and the cell thickness is uniform from 10℃ to 50℃ in the operating temperature range. In addition, when used in the reflection type liquid crystal display, a favorable display quality can be maintained and the cell thickness is uniform from 10℃ to 35℃ in the operating temperature range. In addition, the polymer dispersed type liquid crystal layer 22 is manufactured in the same manner as in the typical polymer dispersed type liquid crystal layer. In other words, the polymer dispersed type liquid crystal layer 22 can be obtained such that a combined material of the polymer precursor and the liquid crystal

material are filled between the substrates through a vacuum injection method, the polymer precursors overlaps by heating or illuminating ultraviolet, and the liquid crystal and polymer are separated from each other.

[0105]

While the glass substrate having transparent electrode is used in the second embodiment, the pillar shaped or non-spherical type spacers may be formed on the light shielding portion of the active matrix substrate having the switching elements formed thereon, in the same manner. In addition, other than the amorphous TFT substrate, the active matrix substrate may be a driving circuit built-in high temperature polysilicon TFT substrate, a low temperature polysilicon TFT substrate, a polysilicon TFT substrate crystallized by other methods such as catalyst, and two-terminal active matrix type substrate, represented by the thin film diode TFD, in conjunction with a planarization process.

[0106]

In the projection display type, dichroic means using a multiplayer interference such as a dichroic mirror may be used, without the color filter. For this reason, of the active matrix substrate having the TFTs formed thereon, by forming a pillar shaped or non-spherical spacer on the counter substrate to correspond a light shielding portion that does not transmit light, e.g., gate signal lines and

source signal lines or intersecting portions thereof, TFT forming portions, and the like, the liquid crystal display device having a favorable display quality and few rough feeling, which can correspond high contrast and high gray level, can be obtained.

[0107]

(Third Embodiment)

Fig. 10 is a cross sectional view of a liquid crystal display device according to a third embodiment of the present invention. The liquid crystal display device of the third embodiment has the same construction as of the polymer dispersed liquid crystal display device described in the second embodiment. In general, for the polymer dispersed liquid crystal display device, when the spacer has low elasticity, the display spot due to the non-uniform thickness is generated. This is because that, in the polymer dispersed type liquid crystal display device, the fluidity of the liquid crystal molecule is extremely small, and it cannot go back to the original state in a rapid temperature change from the high temperature storage. For this reason, while only the uniformity needs to be compensated within the operating temperature range in the first embodiment, the polymer dispersed type liquid crystal display device is also required that the uniformity within the storage temperature range need to be compensated.

Therefore, in order to solve the above problems, for the polymer dispersed type liquid crystal display device according to the third embodiment, the elasticity is given to the spacer in the same method of the first embodiment, and at the same time, from the point of compensating the uniformity within the storage temperature range, more elasticity is given to the spacer than in the second embodiment. For example, in case of the cone type spacer, a degree of tapering is to be larger than the second embodiment, and in case of the hollow type spacer, the hollow area should be larger. In addition, the storage temperature range refers to a surrounding environment temperature when the display device assembling the liquid crystal display device is actually used, and the storage temperature refers to a surrounding environment temperature when the display device assembling the liquid crystal display device is stored. Therefore, in general, the storage temperature range is wider than the operating temperature range. In addition, the polymer dispersed type liquid crystal layer 22 can be manufactured in the same manner in the typical polymer dispersed type liquid crystal layer. In other words, the polymer dispersed type liquid crystal layer 22 can be obtained such that a combined material of the polymer precursor and the liquid crystal material are filled between the substrates through a vacuum

injection method, the polymer precursors are polymerized by heating or illuminating ultraviolet, and the liquid crystal and polymer are separated from each other.

[0108]

The liquid crystal display device according to the third embodiment will now be described below in detail.

[0109]

Referring to Figs. 10a, 10b, and 10c, due to the subsequent rapid temperature change, a structural change generated in the liquid crystal display device according to the present invention will be described.

[0110]

First, Fig. 10a shows a liquid crystal display device at the room temperature (20℃ in the present embodiment). In this state, a pressure of a difference between the atmospheric pressure and the pressure to the substrates 1 and 2 of the combined layer 22 (hereinafter, referred to as an inner pressure of the liquid crystal layer) is applied to two sheets of glass substrates 1 and 2 from the outside, and as a result, the spacer 3 is compressed.

[0111]

Fig. 10b shows a liquid crystal display device when the liquid crystal display device at the room temperature of Fig. 10a is temperature increased to the high temperature (85℃ in the present embodiment). In this state, the inner

pressure of the liquid crystal layer is increased due to heating. According to the present embodiment, a line expansion coefficient of the spacer 3 is $7.0 \sim 10.0 \times 10^{-5}$ (1/K), a line expansion coefficient of the liquid crystal material is 7.0×10^{-4}(1/K), and the line expansion coefficient of the polymer matrix 21 is the same as or less than the expansion coefficient of the spacer 3. In addition, a volume ratio between the liquid crystal 20 for the liquid crystal layer 22 and the polymer matrix 21 is almost 4:1. For this reason, the expansion of the spacer 3 and the polymer matrix 21 can be almost negligible, and the increase of the inner pressure of the liquid crystal layer 22 due to heating depends on the expansion of the liquid crystal 20.

[0112]

Fig. 11 is an example of a relation between the inner pressure Pi of the liquid crystal layer and the repulsive force of the spacer 3 when a temperature of the liquid crystal display device under a constant atmospheric pressure increases or decreases within a predetermined temperature range. In addition, in Fig. 8, the atmospheric pressure is 1.0 kgf/cm^2. The horizontal axis represents a temperature T in a range of 20℃ to 60℃. The vertical axis represents a pressure P in a range of 0.3 kgf/cm^2 to 0.7 kgf/cm^2. In addition, the experiment results of the present inventors verify that even in the temperature range of 0℃ to 85℃, and

in the pressure range of 0.1 kgf/cm^2 to 0.9 kgf/cm^2 shows the same linear characteristics as in Fig. 11. Here, in Fig. 11, the solid line L1 represents a pressure applied to the liquid crystal layer, i.e., the inner pressure Pi of the liquid crystal layer, and a dotted line L2 represents a pressure applied to the spacer 3, i.e., the repulsive force Pr of the spacer 3 per unit area. Hereinafter, the repulsive force of the spacer 3 per unit area is referred to as the repulsive force Pr of the spacer 3.

[0113]

Within the above temperature range, it will be appreciated that both the inner pressure of the liquid crystal layer and the repulsive force Pr of the spacer 3 exist, and their summation is the same as the atmospheric pressure. In other words, the liquid crystal display device resists the atmospheric pressure through the inner pressure of the liquid crystal layer and the repulsive force Pr of the spacer 3.

[0114]

When the inner pressure of the liquid crystal layer increases in proportional to the increase of the temperature, the repulsive force Pr of the spacer 3 decreases, while the spacer 3 always has the repulsive force Pr in the temperature range of 20℃ to 60℃ according to the present example (which is also true in a range of 0℃ to 85℃). In

other words, the compressed spacer lifts up the glass substrates 1 and 2 from the inside through the repulsive force Pr at a place where the liquid crystal layer 22 reaches, and then holds the compressed state. As a result, as shown in Fig. 10b, a gap width is uniformly widened other than the peripheral portion fixed to the sealing portion 7.

[0115]

Fig. 10c shows a liquid crystal display device with a temperature rapidly decreasing from the high temperature state shown in Fig. 10b to the room temperature. As shown in Fig. 10b, when the liquid crystal display device in the high temperature is cooled, the inner pressure of the liquid crystal layer is reduced and the repulsive force Pr of the spacer 3 increases. In other words, the expanded liquid crystal layer 22 contracts while the glass substrates 1 and 2 and the spacer 3 always contact with each other. For this reason, the liquid layer 22 will not have a different degree of contraction depending on the location, and thus uniformly contracts on the overall place. As a result, even when the temperature rapidly drops from the high temperature state, it perfectly goes back to the original state (Fig. 10a), as shown in Fig. 10c.

[0116]

When the elastic body is not used in the spacer, since a moving speed of the polymer matrix of the liquid crystal

molecule slows for the polymer dispersed type liquid crystal, even when the temperature turns back to the room temperature, the liquid crystal does not go back to its original state, so that its central portion is thick, and a thickness around the main sealing portion is thinner, and as a result, the display spot is provided.

[0117]

In addition, when the temperature of the liquid crystal display device decreased to the low temperature (e.g., 0℃), the thickness Tc of the liquid crystal layer is reduced, however, even in this case, the thickness Tc of the liquid crystal layer 22 maintains constant due to the repulsive force Pr of the spacer 3, as shown in Fig. 10. In addition, at the low temperature as well, the inner pressure of the liquid crystal layer exists, and thus the liquid crystal display device resists the atmospheric pressure through the repulsive force Pr of the spacer and the inner pressure of the liquid crystal layer.

[0118]

As described above, as long as the spacer 3 is elastically deformed, the distortion of the gap width, i.e., the derivative of the thickness Tc of the liquid crystal layer, between two sheets of glass substrates due to the temperature change can be prevented. In addition, while the liquid crystal display device has been described as a

transparent type liquid crystal display device, i.e., a transparent glass substrate including transparent electrode on either of a pair of substrates in the present embodiment, a reflection type liquid crystal display device having the same effect of the present invention can be provided using the reflection electrode that reflects light instead of the transparent electrode.

[0119]

In addition, it may also be appreciated that, in order to arrange the reflection type liquid crystal display device, the reflection electrode divided for each pixel rather than the transparent electrode 6 is arranged, and the voltage is supplied from the TFT device to the reflection electrode.

[0120]

In addition, although in the foregoing description the temperature range is 0℃ to 85℃, as long as the inner pressure of the liquid crystal layer and the repulsive force Pr of the spacer 3 exist and their summation is the same as the atmospheric pressure, the effect of the present invention can be obtained, and the temperature range is not limited hereto.

[0121]

While the present invention has been described in detail, as a type having the polymer matrix and the liquid crystal in the polymer dispersed type liquid crystal display

device, a PN (polymer-network) type where polymer compounds distributes in the liquid crystal forming a continuous phase in a 3-D net shape or fine particle droplet shape may be used in the same manner, rather than NCAP (nematic-curvilinear-aligned-phase) type where droplets distribute in the polymer matrix as shown in the embodiment.

[0122]

In addition, while a combined material of the polymer precursor and the liquid crystal material are filled in the liquid crystal display device through a vacuum injection method according to the second and third embodiments, the combined material of the polymer precursor and the liquid crystal material may be injected into the liquid crystal display device under the pressure, and thus the same effect can be obtained.

[0123]

In addition, while the elastic spacer is formed on the substrate having transparent electrode at least one substrate, in order to maintain a constant cell thickness between a pair of substrates in the first to third embodiments, the spacer may be formed on the light shielding portion of the active matrix substrate having the switching elements formed thereon, using the same method. In addition, other than the amorphous TFT substrate, the active matrix substrate may be a driving circuit built-in high temperature

polysilicon TFT substrate, a low temperature polysilicon TFT substrate, a polysilicon TFT substrate crystallized by other methods such as catalyst, and two-terminal active matrix type substrate, represented by the thin film diode TFD, in conjunction with a planarization process.

[0124]

In addition, while in the first to third embodiments, it is configured that both a rapid temperature change from the room temperature to the low temperature, and a rapid temperature change from the room temperature to the high temperature may follow the spacer, it can be configured that only one of a rapid temperature change from the room temperature to the low temperature, and a rapid temperature change from the room temperature to the high temperature may follow the spacer.

[0125]

[Effect]

As described above, according to the present invention, the spacer is in an elastically deformed state, so that the liquid crystal display device can be provided that can follow even when the liquid crystal molecule contracts due to a rapid temperature change from the room temperature to the low temperature, so that the liquid crystal display device having a favorable display quality can be provided without, so called, a low temperature discharging when used

at the low temperature. In addition, when used at the high temperature as well, the liquid crystal display device having a favorable display quality can be provided without non-uniform cell thickness. In addition, within the operating temperature range, the polymer dispersed type liquid crystal display device having a favorable display quality can be provided without a low temperature discharging and non-uniform cell thickness. In addition, by forming a pillar shaped or non-spherical spacer in advance on the light shielding portion of the counter substrate or the active matrix substrate, the liquid crystal display device having a favorable display quality and few rough feeling, which can correspond high contrast and high gray scale, can be obtained.

[0126]

In addition, within a temperature range that stores the polymer dispersed type liquid crystal display device, a distortion of a gap width between two sheets of glass substrates due to the temperature change, i.e., a derivative of the thickness of the liquid crystal layer can be prevented, and thus the uniformity of the display image can be improved.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a cross-sectional view of a liquid crystal display device according to a first embodiment of the present invention.

[Fig. 2]

Fig. 2 is a processing diagram of manufacturing a liquid crystal display device according to a first embodiment of the present invention.

[Fig. 3]

Fig. 3 is a diagram for explaining a spacer shape for use in a liquid crystal display device according to a first embodiment of the present invention.

[Fig. 4]

Fig. 4 is a diagram showing an example of a deformed spacer.

[Fig. 5]

Fig. 5 is a diagram for explaining a deforming amount of the spacer.

[Fig. 6]

Fig. 6 is a diagram for explaining a state where the liquid crystal display device according to the first embodiment of the present invention is exposed to an environment from the room temperature to -20° C.

[Fig. 7]

Fig. 7 is a diagram for explaining a state where the liquid crystal display device according to the first

embodiment of the present invention is exposed to a high temperature environment from the room temperature to 40° C.

[Fig. 8]

Fig. 8 is a graph showing a relation between an inner Pressure Pi of the liquid crystal layer and a repulsive force Pr of the spacer, when a temperature of the liquid crystal display device under a constant atmospheric pressure increases or decreases within a predetermined temperature range, for the liquid crystal display device according to the first embodiment of the present invention.

[Fig. 9]

Fig. 9 is a cross sectional view of a liquid crystal display device according to a second embodiment of the present invention.

[Fig. 10]

Fig. 10 is a diagram showing a state where a spacer is changed within a storage temperature range, for the liquid crystal display device according to a third embodiment of the present invention.

[Fig. 11]

Fig. 11 is a graph showing a relation between an inner Pressure Pi of the liquid crystal layer and a repulsive force Pr of the spacer, when a temperature of the liquid crystal display device under a constant atmospheric pressure increases or decreases within a predetermined temperature

range, for the liquid crystal display device according to the third embodiment of the present invention.

[Fig. 12]

Fig. 12 is a diagram for explaining a low temperature discharging phenomenon for a liquid crystal display device of the prior art.

[Fig. 13]

Fig. 13 is a diagram showing a distortion of a gap width (i.e., thickness derivative of a liquid crystal layer) between substrates, for a polymer-dispersed type liquid crystal display device of the prior art.

[Fig. 14]

Fig. 14 is a diagram for explaining a state where the liquid crystal display device according to a comparative example of the first embodiment of the present invention is exposed to a high temperature environment from the room temperature to 40° C.

[Fig. 15]

Fig. 15 is a graph showing a relation between an inner Pressure Pi of the liquid crystal layer and a repulsive force Pr of the spacer, when a temperature of the liquid crystal display device under a constant atmospheric pressure increases or decreases within a predetermined temperature range, for the liquid crystal display device according to a comparative example of the first embodiment of the present

invention.

[Reference Numerals]

1, 2: substrate

3: spacer

4: liquid crystal layer

5, 6: transparent electrode

7: sealing portion

22: polymer dispersed type liquid crystal layer